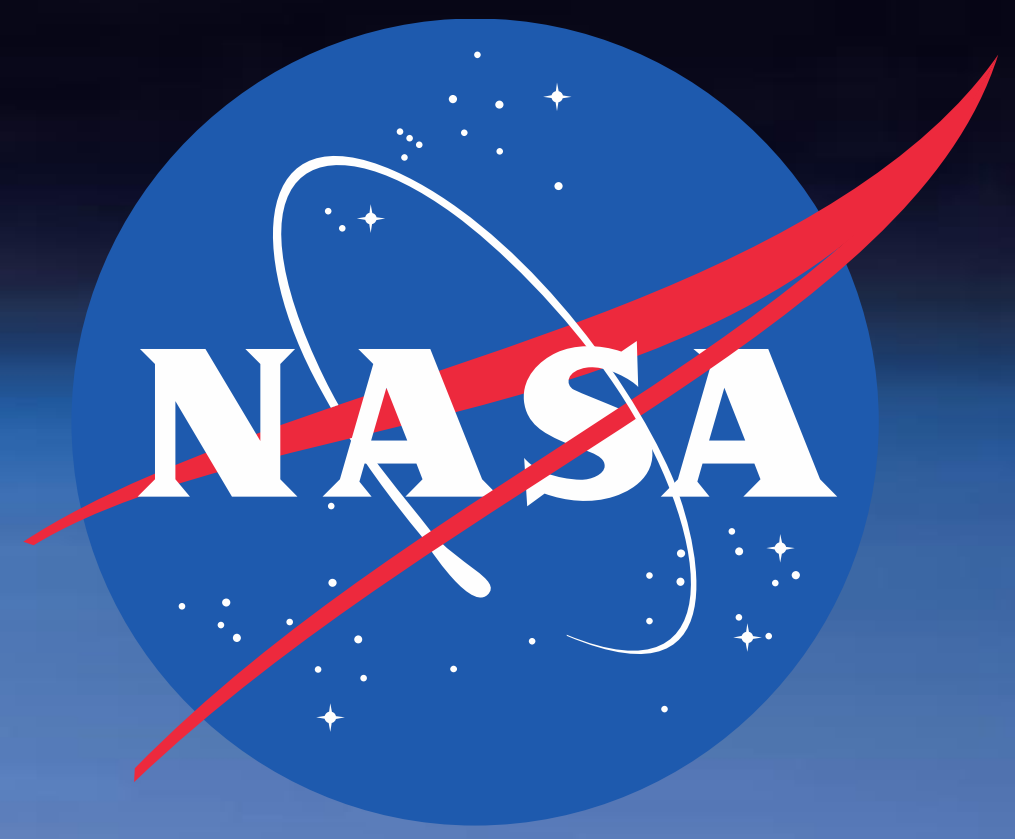# IMPACT OF +G$_z$ TO –G$_z$ INDUCED FLUID SHIFTS ON OCULAR AND CEREBRAL PARAMETERS DURING SIMULATED ORION RE-ENTRY

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BACKGROUND

- All long-duration International Space Station (ISS) crewmembers experience some degree of visual impairment and ocular structural changes during and after spaceflight, ranging from slight changes in visual acuity to papilledema, choroidal folds, cotton wool spots, and permanent vision impairment.

- It is unclear if this visual impairment only occurs while in the spaceflight environment or if the ocular changes are exacerbated due to the rapid fluid shifts associated with re-entry and landing on Earth.

- Future vehicle re-entry profiles will cause +Gz (head-to-foot) stress during re-entry followed by a rapid change in posture at deployment of the parachute, resulting in a headward stress (-Gz) of up to -0.3 Gz for an extended period of time, approaching 10 minutes.

- This rapid Gz transition, first pulling +Gz caudally, then pushing –Gz in a cephalad direction, known as a 'pull-push effect' on bodily fluids, might exacerbate existing ocular pathologies associated with long-duration spaceflight.

- Further, these ocular pathologies might be aggravated by anti-orthostatic countermeasures, including fluid loading, legs-up posture and compression garments. These countermeasures are routinely employed during re-entry and landing, but may potentiate the discomfort associated with head-down posture during re-entry and may lead to further damage.

SPECIFIC AIMS

Specific Aim 1: To determine the impact of sequential +Gz followed by -Gz stress on cerebrovascular and ocular structure and function without the orthostatic intolerance countermeasures normally applied in astronauts returning from spaceflight.

Hypothesis: Following +Gz exposure, –Gz exposure will increase jugular vein distention and pressure, increase intraocular and intracranial pressure, and distend optic nerve sheath diameter but not change cerebral blood flow velocity.

Specific Aim 2: To determine the effect of anti-orthostatic countermeasures (fluid loading, gradient compression garments, legs up posture with foot pressure) on the +Gz to -Gz induced fluids shift and subsequent impact on cerebral and ocular structure and function.

Hypothesis: The addition of the anti-orthostatic countermeasures will exacerbate ocular and vascular effects induced by the head-down tilt (HDT) fluid shift and will overcome the ability of cerebral autoregulation to minimize these changes resulting in clinically significant elevations in intracranial pressure (ICP).

METHODS

- 10 normal, healthy volunteers with characteristics similar to the astronaut population will be recruited to participate in this study.

- Each subject will visit the laboratory on two different days to simulate the +Gz to –Gz "pull-push" (80° head-up tilt for 2 minutes to simulate +1 Gz, followed by a 10° head-down tilt for 10 minutes to simulate -0.2 Gz, Figure 1) under normovolemic conditions and while utilizing anti-orthostatic countermeasures designed to cause cephalad fluid shift.
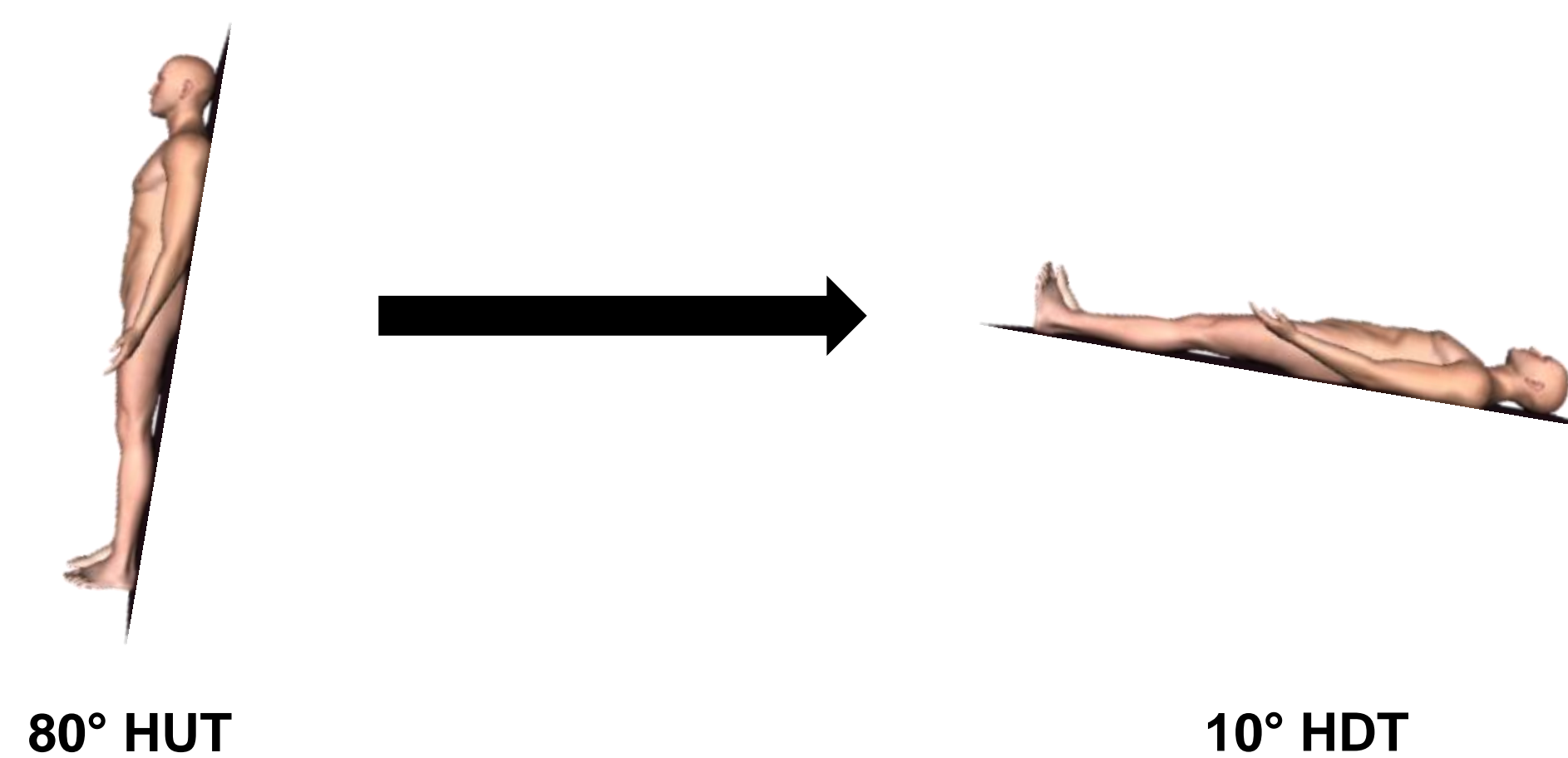

80° HUT → **10° HDT**

Figure 1: The "Pull-Push" effect will be investigated with 80° head-up tilt followed by 10° head-down tilt.

- Anti-orthostatic countermeasures include:
  - Gradient compression garments that provide 55 mmHg of compression at the ankle decreasing up the leg to ~15 mmHg at the abdomen
  - Isotonic fluid loading (volume dependent on subject mass)
  - Legs-up posture
- During all phases of testing, electrocardiogram, blood pressure, and middle cerebral artery blood velocity will be continuously acquired. These signals will be used in a dynamic linear model to estimate intracranial pressure (Figure 2).
- Intraocular pressure will be measured with Icare Pro Tonometer.
- Intracranial pressure will be estimated during HDT posture using a tympanic membrane technique (Figure 3).
- Internal jugular vein pressure and area will be acquired via ultrasound (Figure 4).
- Optical coherence tomography will be used to assess choroid engorgement (Figure 5) and optic disc displacement (Figure 6).
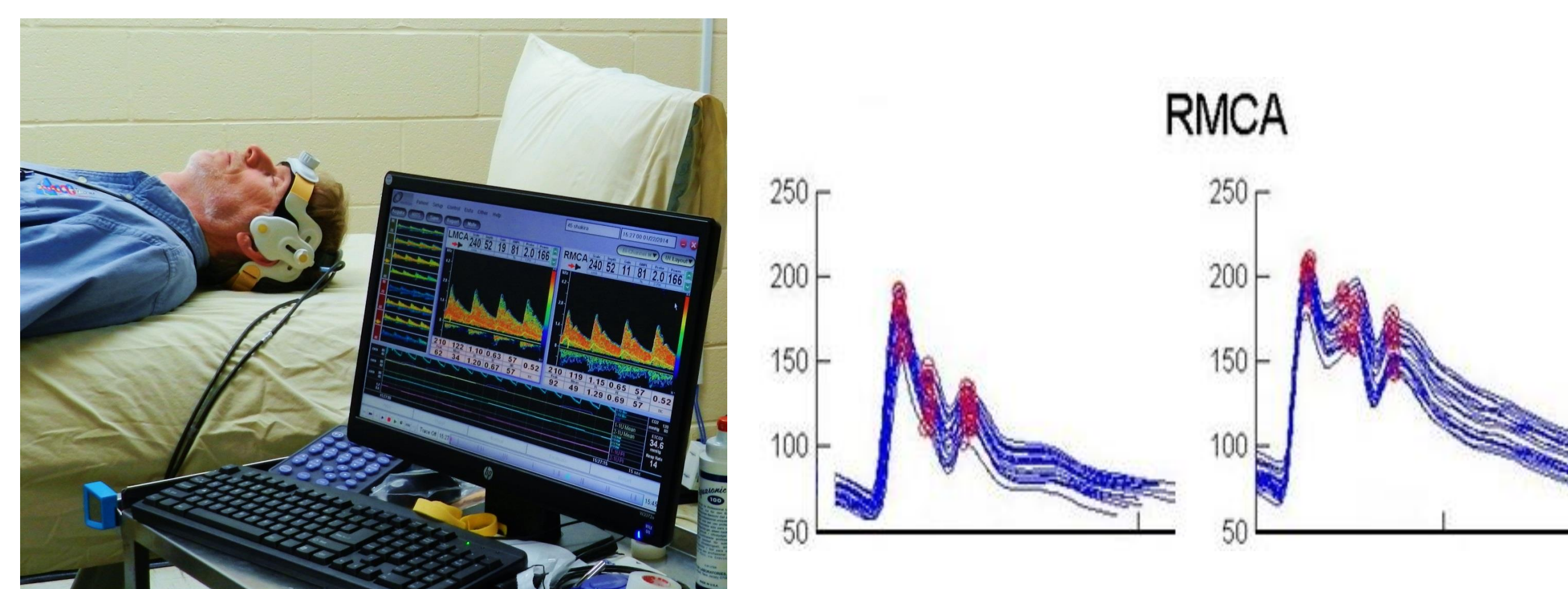

Figure 2: Left: Bilateral transcranial Doppler of the middle cerebral artery. Right: Model output showing right middle cerebral artery (RMCA) blood flow velocity waveforms (reflective of changes in ICP) when moving from an upright (left) to supine (right) posture. Model created using a dynamic linear model with middle cerebral artery velocity, continuous blood pressure electrocardiogram signals for cardiac cycle gating.
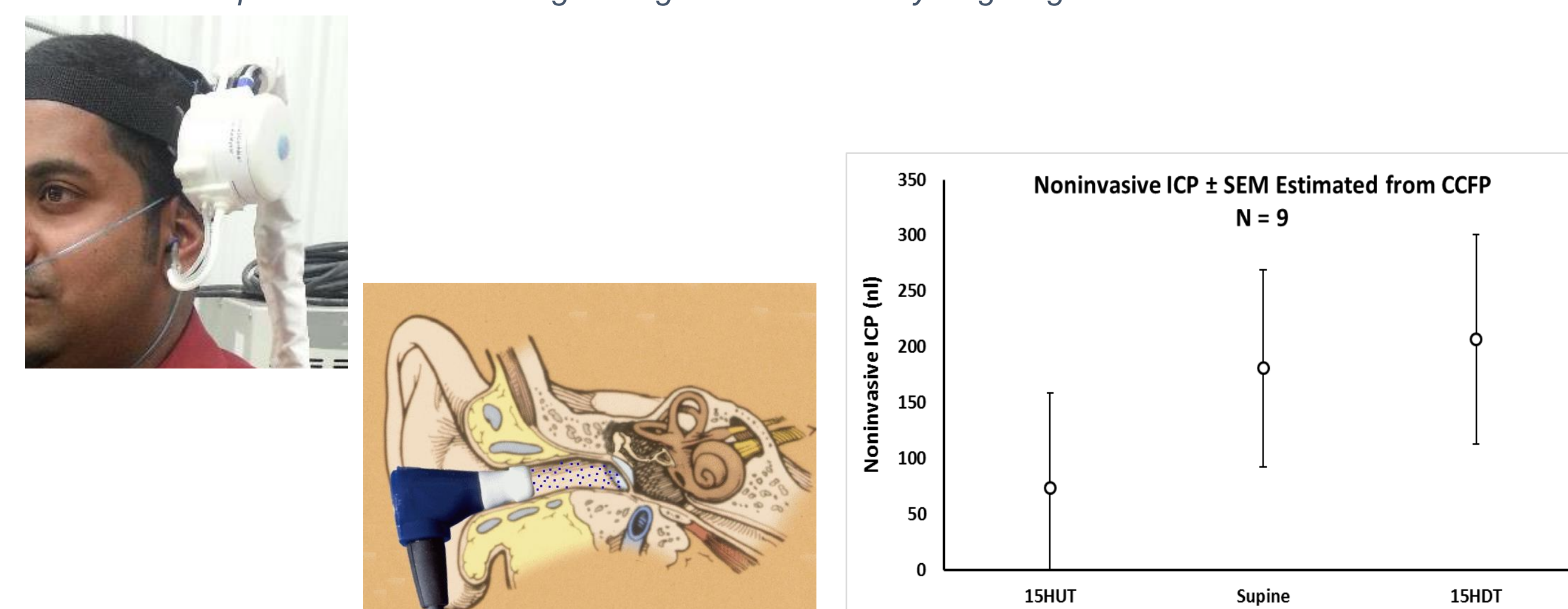

Figure 3: Tympanic membrane displacement as an indicator of changes in intracranial pressure. Pilot data showing changes in ICP when moving from 15° head-up tilt to supine and to 15° head-down tilt.
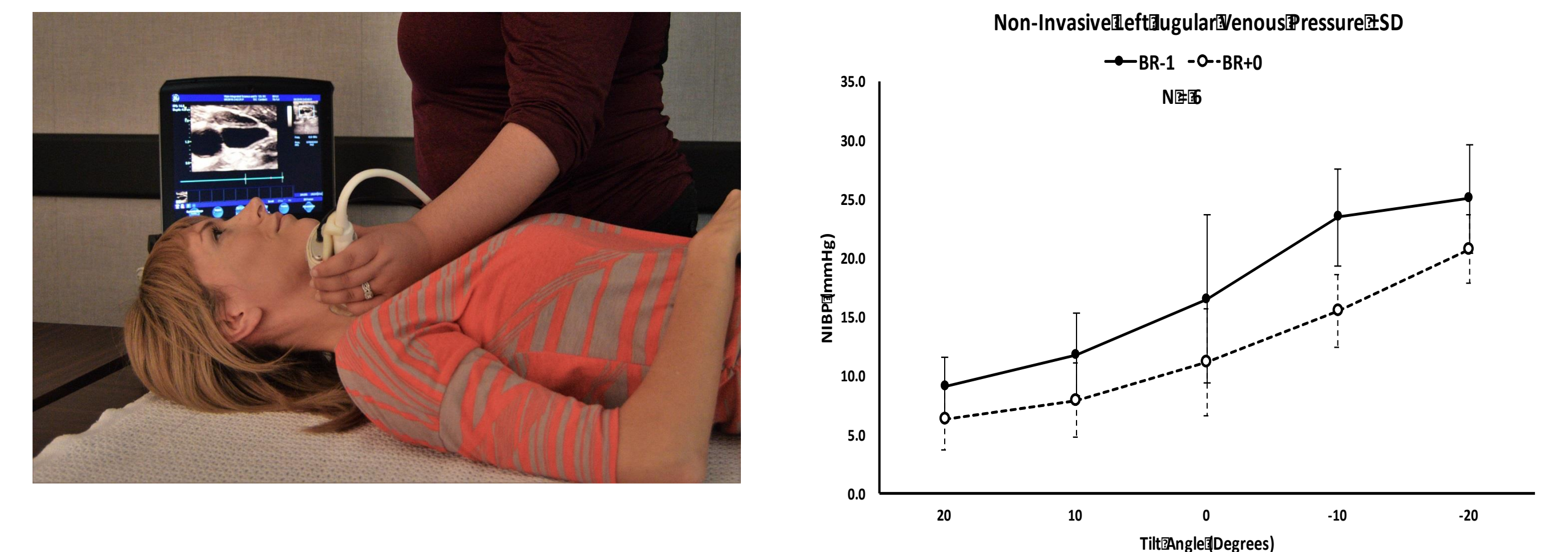

Figure 4: Jugular venous pressure acquired by compression sonography. Jugular venous pressure increases from 20° head-up tilt to 20° head-down tilt as acquired by the VeinPress non-invasive venous pressure monitor. Along with measures of vein area, can be used to assess venous compliance. Example data from previous bed rest study.
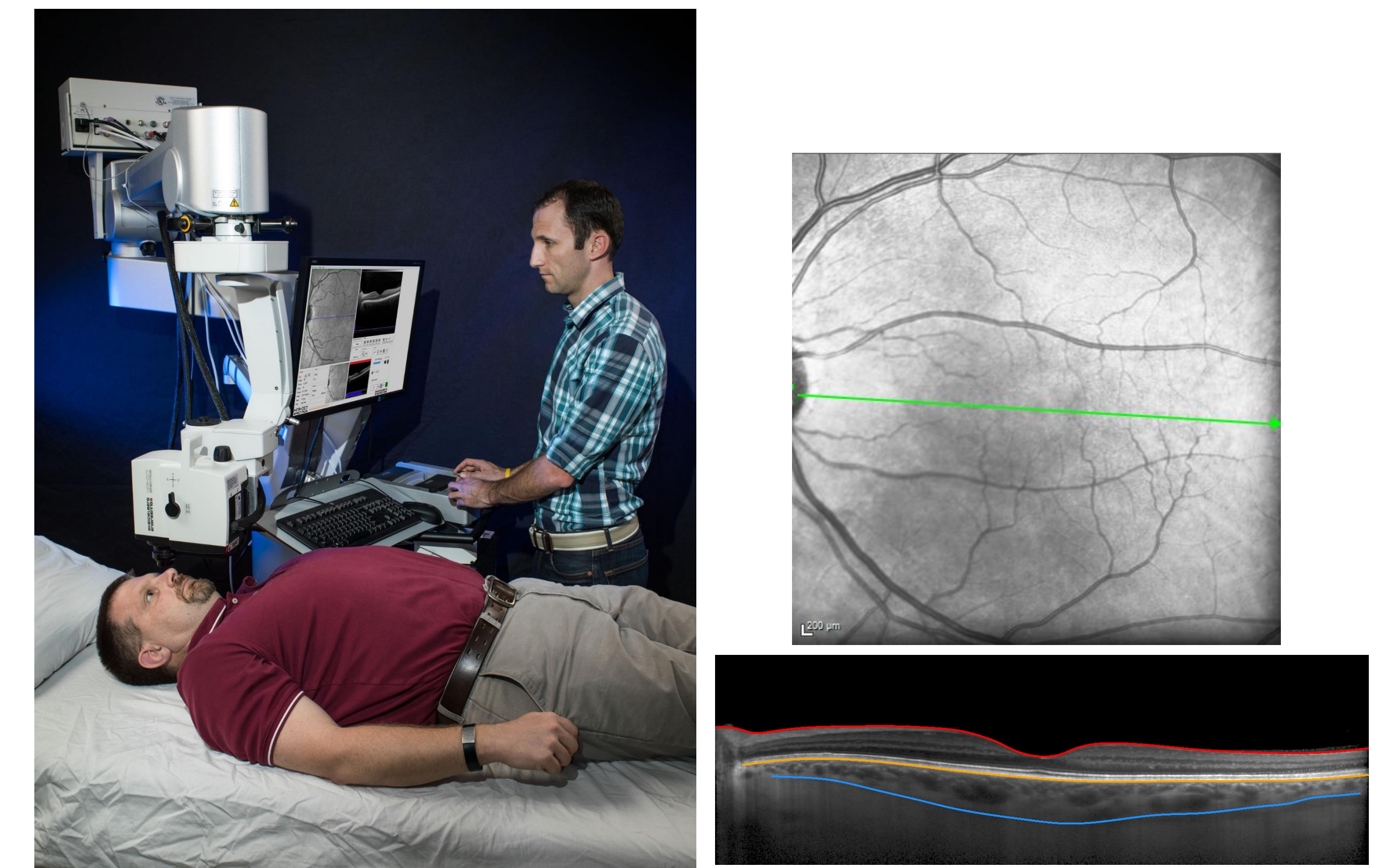

Figure 5: Left: Optical coherence tomography acquired during supine posture using surgical arm-mounted camera. Right: Example OCT image of a single retinal line scan through the macula. Commercial software is used to assess the changes in choroid thickness (blue line).
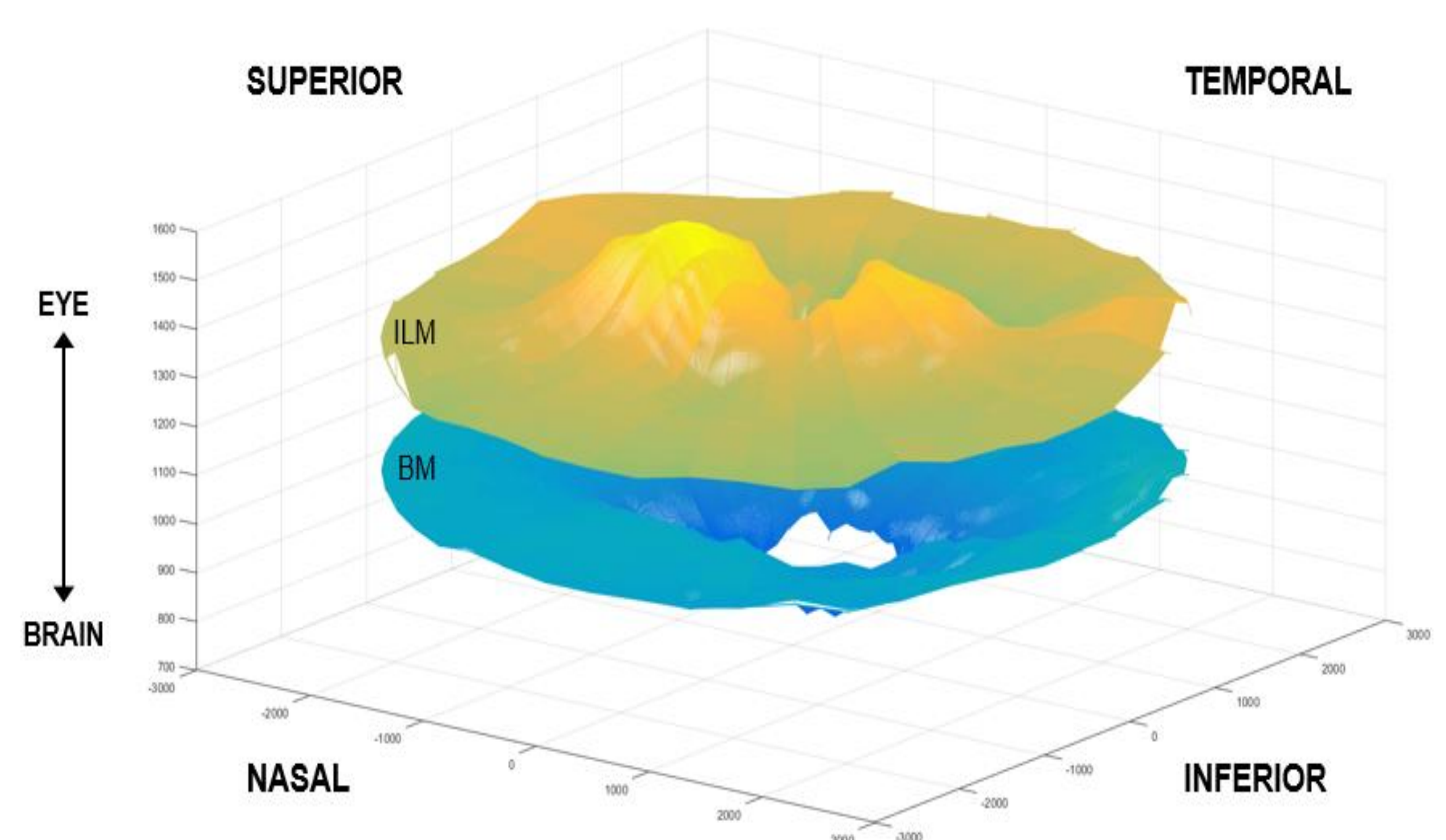

Figure 6: Example image created from custom software to delineate the internal limiting membrane (ILM) and Bruch's membrane (BM). This type of analysis can be used to visualize separation of these layers and movement of the optic nerve head between the conditions outlined in this proposal.

Study will begin in Spring 2017 with targeted completion by end of 2017.

References

Bungo MW, Charles JB, Johnson PC Jr (1985) Cardiovascular deconditioning during space flight and the use of saline as a countermeasure to orthostatic intolerance. Aviat Space Environ Med 56:985–990.

Mader TH, Gibson CR, Pass AF, et al (2011) Optic disc edema, globe flattening, choroidal folds, and hyperopic shifts observed in astronauts after long-duration space flight. Ophthalmology 118:2058–2069. doi:10.1016/j.ophtha.2011.06.021

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